FDCD WORKING PAPER

CORN: EFFECTS OF WEATHER, STAGES OF DEVELOPMENT, PLANTING AND HARVESTING TIMES, WORLD PRODUCTION AND MAJOR PRODUCERS

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January 1976

Foreign Demand and Competition Division

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PREFACE

The main purpose of this paper is to provide a general, non-technical discussion of the growth and development of corn and how it is affected by weather. It was written particularly for the use of country analysts who are concerned with corn production in foreign countries, as well as for anyone else interested in the growth and development of the crop.

Comments and suggestions are welcomed and should be given to the author in Room 396-GHI, Ext. 79112.

PREFACE

The main purpose of this paper is to provide a general, non-technical discussion of the growth and development of corn and how it is affected by weather. [illegible] of [illegible] and [illegible] of [illegible] as [illegible] of the [illegible] growth and development of the crop.

Comments and suggestions [illegible] will [illegible] to the author (J. [illegible], [illegible] 1971).

INTRODUCTION

Corn is an important crop, used both for human food and livestock feed. It comprises approximately one-fourth of total world grain production (see table 1). Thanks to modern cultural practices, advanced farm technology and the introduction and improvement of hybrid corn, the cultivation of corn has spread to a wide variety of locations throughout the world. "Corn has such a remarkable diversity of vegetative types that sorts adapted to nearly all environmental conditions are in cultivation; corn is now more widely distributed over the world than any other cereal crop... It is produced from below sea level in the Caspian Plain to altitudes of more than 12,000 feet in the Peruvian Andes." 1/

Many factors influence the production of a corn crop, such as soil fertility, soil conditions, time of planting, seed variety, weeds, insects, and weather. Weather--the one factor over which man has little, if any, control--has a very significant impact on the development, and ultimately the yield and production, of corn. The following discussion illustrates the impact various weather factors have on a corn plant during its stages of growth.

Normally corn plants follow the same general pattern of development as given in the first description below. However, it should be emphasized that the different varieties 2/ and hybrids 3/ have a wide range of requirements for and tolerances of weather conditions. For example, early-maturing varieties and hybrids have been developed which are suitable for growing in the northern U.S. and Canada, while others have been adapted to tropical climates. Hence, such a description

of development must necessarily be quite generalized with respect to variables such as temperature, amount of moisture, sunlight requirements, and length of stages of development.

The second description below lists the stages of growth according to the number of fully emerged leaves and the kernel development on the ear. This, too, is approximate, since the duration of the stages and the number of leaves which develops in the corn plant may vary widely with different hybrids, different seasons, different planting dates and different locations. This second description given is for an adapted, mid-season hybrid in central Iowa.

GENERAL CLIMATIC CONDITIONS

Temperature

For optimum growth, corn requires high temperatures both day and night during the growing season. Mean summer temperature should be 70^{o} to 80^{o} F. Under normal field conditions, maximum temperatures should be between 85^{o} and 90^{o} F. Mean night temperatures during summer should be 58^{o} F or above. Contrary to popular belief, low to moderate nighttime temperatures (50^{o} to 75^{o} F) are better than high temperatures. At high temperatures respiration proceeds too rapidly, while at too low temperatures normal growth processes proceed too slowly. Extremely high temperatures, especially when accompanied by deficient moisture, may be injurious, particularly during the tasseling stage.

The corn plant can be injured by freezing temperatures at any time during the growing season, but early fall frosts are most serious. Most

strains cannot recover from freezes which occur when the growing point is above soil surface. Frosts early in the fall before the grain is mature kill the leaf tissue, reduce yield and damage quality.

Moisture

For optimum growth and grain production, corn needs a plentiful supply of moisture, well-distributed throughout the growing season. A rule of thumb is that an average corn crop needs 20 inches of water, but water requirements actually vary widely from year to year, depending upon the temperature. Corn's moisture requirement is fairly low relative to other crops, since a relatively small number of pounds of water is required for each pound of dry matter produced. Yet the per acre water requirement is high because of the potential high production per acre.

Moisture is especially important during the period of rapid growth, pollination, and grain development. Maximum amounts of moisture are needed during tasseling and silking, which occur immediately before and after pollination. These are the key times to supply water where irrigation is available.

Seasonal moisture requirements are dependent upon seasonal evaporation which, in turn, is influenced by temperature, humidity, and wind movement. Moisture supply determines the upper temperature limit that is favorable for growth. With abundant moisture, corn will grow well at temperatures above 95° F, but under normal field conditions, maximum temperatures between 85° and 90° F are nearer optimum. When moisture is short, cool temperature helps the plant to tolerate moisture stress.

Sunlight

Abundant amounts of sunlight are needed for maximum yields. Corn does not grow normally in the shade or during extended periods of cloudy weather. Nearly 80 percent of the grain produced by corn is laid down in a 30-day period starting about ten days after fertilization of the kernel. Cloudiness during that period can sharply limit yields.

STAGES OF DEVELOPMENT

Seedbed preparation

The ideal seedbed is fine and firm enough for good seed-soil contact but not so fine that it runs together and crusts upon drying. If the seedbed is too coarse, it dries out more quickly and there is not enough soil contact with the corn kernel to assure rapid moisture transfer to the kernel for quick germination.

In preparing a seedbed, the goals are: (1) to provide a suitable place for the seed to germinate and for seedling roots to obtain both moisture and nutrients; (2) to cover or incorporate trash to the extent necessary for planting and cultivating with the available equipment; (3) to kill annual weeds and severely set back perennials; (4) to provide a surface that is well-cultivated, that will permit rapid infiltration of rainfall, and one that will not form a crust upon drying.

Planting

There is a strong potential for increasing yields through early planting, especially when combined with adequate nitrogen and optimum population. The best guide to date of planting is a combination of soil temperature

and calendar date. Yields decrease with late plantings independent of the soil moisture level. This phenomenon is apparently associated with lower average air temperatures during the ear formation period for late planted corn.

Germination

The organs of the embryo, which remained dry in the dormant seed, resume growth. The primary root breaks through the walls, or sheaths, surrounding it, and then makes its way downward. This occurs in 35 to 55 hours. Plumules then ascend to the soil surface. Within a few days after the first root emerges, several other seminal roots arise from near the same site and proceed outward and downward.

High temperatures are desirable for germination. Only a few strains can germinate satisfactorily below 50° F. The rate of germination increases rapidly with increasing temperature. At 55° F and below, germinating seedlings of most strains are especially susceptible to disease. Warm weather after planting hastens germination and early growth. Optimum temperature for germination is 86° F.

Lack of moisture is not usually a widespread problem for corn germination. Corn is planted relatively early before the soil dries in most producing areas.

Emergence

The seedling breaks through the soil surface. Under ideal conditions, corn kernels germinate quickly and seedlings emerge within five or six days after planting. Average time for emergence is seven to twelve days. Low soil temperature is the most common cause of slow

emergence of corn seedlings. About the time the seedling emerges, the main root system begins to form above the first roots. Nearly all leaves that will appear on the corn plant already exist in the embryo of the kernel at planting time. Highly favorable conditions, especially warm temperature, during the first seven to ten days after emergence may add one to three additional leaves to the mature plant. Total number of leaves is finally determined by the time the plant is five to ten inches tall. Until the plant reaches this height, the growing point remains below soil surface. This is significant because mechanical injury or a freeze at this time probably will not kill it. It may actually have little effect on later growth and final yield.

Tasseling

When the growing point is still below the ground and the plant is five to ten inches tall, the last leaf is differentiated at the tip and a miniature tassel begins to form. Then miniature ear shoots soon form in several of the leaf axils. 4/ All of the major parts of the plant are now present, though some remain hidden for weeks within the roll of yet unrolled leaves. When the plant has achieved about one-fourth of its final height, a "grand period" of growth begins. Increases of one to two inches a day are common. Gradually the growth rate diminishes in the lower part of the stem, but accelerates in the upper part, with the result that the tassel is thrust out quite rapidly. The ear shoot in the leaf axil, about midway up the plant appears first but is usually a few days behind tassel emergence. During the tasseling

stage, high temperatures and low humidity can cause extreme dessication, which may kill the leaves and tassels and prevent pollination.

Pollination

A few days after the tassel is fully expanded, the anthers 5/ are thrust out and pollen shedding begins. This normally continues for seven to ten days.

Silking

Silks on the first ear shoot begin to emerge from the ear tip one to four days after pollen shedding begins. This delay in silking is the natural mechanism to reduce the amount of self-fertilization. The time from germination to silking is advanced or retarded markedly by temperature.

Fertilization

Pollen moves down the tubes of the silk and fertilizes the ovule, which then causes the seed to start growing. Fertilization of the ovules that develop into kernels extends over several days, beginning about one-third of the way up from the base of the plant and proceeding in both directions. The overall favorableness of conditions in the plant during this crucial, generally short time period of approximately one to three days determines how many fertilized ovules will begin to form kernels. During this time the physiological mechanism within the plant adjusts the size of the ear to the likely capability to produce mature grain. High plant population, weed competition, moisture stress, shortage of nutrients, or several days of low light intensity reduce ear length.

Once the kernels are set, the number of kernels cannot be increased. Only the kernel size can be influenced by conditions during the rest of the season. Poor kernel set is generally caused by stress conditions within the plant or injury to silks by insects, and sometimes by poor timing of pollen shed and silk receptiveness. From pollination to fertilization of ovule may require less than one day.

Grain development

The kernel sack is at first filled with a nearly clear sweet liquid, but this soon turns milky and then deposition of dry matter becomes evident. Physiologic maturity is the time when the grain on a plant has reached its maximum dry weight, i.e. when the grain contains 30-35 percent moisture. There are several indications that maturity has been reached. The maturity line on the kernels extends inward to the cob; no milk can be squeezed from the tips of the kernel next to the cob when punctured with the thumbnail; the kernels shell off the cob fairly easily; the shucks are dry and beginning to open up; and no green foliage is present. Fertilization to maturity takes about 50 to 60 days. The length of time from silking to maturity seems to be influenced little by weather conditions.

Harvesting

Corn for seed is usually harvested as soon as possible after physiologic maturity. Commercial corn is normally harvested at about 26 to 28 percent moisture if it is to be artificially dried, while the moisture content should be even lower for cribbed corn. The

main reason for prompt harvesting after corn reaches 28 percent moisture is that losses mount rapidly from lodging due to stalk rots and wet, stormy weather.

SIGNIFICANT WEATHER FACTORS DURING STAGES OF CORN GROWTH

Stage of Growth	Weather Factors
Planting	Time of planting is an important determinant of yields. Potential yields increase with earlier plantings and decrease as planting time is later and later, independent of soil moisture level. This apparently results from lower average air temperatures that are prevalent during the ear-formation period for late-planted corn.
Germination	High temperatures are desirable, because they speed up germination and early growth. Optimum temperature is around 86°F. Soil moisture supplies are usually adequate at this stage, as corn is planted before the soil dries in most producing areas.
Emergence	The length of time between planting and emergence is influenced by soil temperature, which is also a factor of the depth at which the seed is planted. Very favorable conditions, especially warm temperatures, during the first seven to ten days after emergence, can add one to three additional leaves to the mature plant. Conditions during the period from seedbed preparation through emergence determine the length of the cob. Lack of moisture or some other factor causing stress may result in drastically shortened cob length. After this time, cob length will not be be increased, even under optimum weather conditions.
Tasseling	A period of rapid growth. High temperatures and low humidity can cause abnormally small leaf area, extreme dessication which may kill the leaves and tassels and prevent pollination, and decrease the plant's ability to transfer nutrients to the developing ear at a later stage.

Stage of Growth	Weather Factors
Pollination Silking Fertilization	Weather is crucial. Hot, dry weather results in poor pollination and seed set. The silks shrink, preventing pollen from growing down the tiny tubes of the silk and fertilizing the ovule, which then causes causes the seed to start growing. The silk must remain moist for pollination to occur. Once the kernels are set, the number of kernels cannot be increased. Only the kernel size can be influenced by conditions during the rest of the season.
Grain development	Grain weight begins a rapid increase and adequate moisture is important. Unfavorable conditions will cause unfilled kernels and "chaffy" ears. Drought may cause some loss in yield, due to both smaller kernels and abortion of the fertilized ovules.
Maturity Harvest	Warm, dry weather results in fast drying, less incidence of stalk rot. Wet weather results in slower drying and greater liability to stalk rot.

STAGES OF CORN GROWTH ACCORDING TO THE NUMBER OF EMERGED LEAVES AND KERNEL DEVELOPMENT

Emergence	Stage 0 - plant tip emerges from the soil	The depth at which the seed is planted influences the length of time from planting to emergence. Seedlings from deep-planted seeds have a greater depth of soil to penetrate. Also, temperatures are cooler at greater depths and growth is slower
	Stage 0.5- 2 leaves fully emerged, 1 week after plant emergence Stage 1 - 4 leaves fully emerged, 2 weeks after plant emergence Stage 1.5- 6 leaves fully emerged, 3 weeks after plant emergence Stage 2 - 8 leaves fully emerged, 4 weeks after plant emergence	Flooding during any of this time when the growing point is below the soil surface can kill corn plants in a few days, especially if temperatures are high. At later stages, when the growing point is above water, flooding is not as detrimental.
Period of Rapid Leaf Formation	Stage 2 - 8 leaves fully emerged, 4 weeks after plant emergence Stage 2.5- 10 leaves fully emerged, 5 weeks after plant emergence	The stalk is now growing well above the soil surface. Plants broken over below the growing point will not recover. Yield losses from hail or leaf damage is greater now than at any previous stage.
	Stage 3 - 12th leaf fully emerged, 6 weeks after plant emergence	A critical period in determining the size of the uppermost ear. Moisture or nutritional deficiencies may seriously reduce the potential size of the ear that will be harvested. Potential size of harvested ears is also related to the length of time between Stage 3 and silking (Stage 5).

	Stage 3.5- 14th leaf fully emerged, 7 weeks after plant emergence	The number of ovules which develop silks, and thus the number of kernels, is being determined during this time.
Tasseling	Stage 4 - 16th leaf fully emerged, 8 weeks after plant emergence	Moisture stress or nutrient deficiencies usually increase in intensity from the top to the bottom of the plant and will delay silking more than it will tassel emergence and pollen shedding. Complete leaf removal by hail will cause essentially complete loss of grain yield.
Pollination Silking	Stage 5 - Silks emerge, pollen shedding, 66 days after emergence	The number of ovules that will be fertilized is being determined. Moisture stress (hot, dry days) or nutrient deficiency may result in poor pollination and seed set. Early planting would allow this stage to occur when climatic conditions are most likely to be favorable.
Grain Development	Stage 6 - Blister stage, 12 days after silking	Grain weight begins rapid increase. Adequate moisture is very important. Irrigation is advisable if possible.
	Stage 7 - Dough stage, 24 days after silking	The period of rapid increase in grain weight and development of the young plant in the embryo of each seed. Unfavorable conditions or nutrient deficiencies will cause unfilled kernels and "chaffy" ears.
	Stage 8 - Beginning dent stage. A few kernels are showing dents, 36 days after silking	Continuation of rapid grain weight increase and development of young plant in embryo of each seed.
	Stage 9 - All kernels fully dented, 48 days after silking	

Maturity Harvest	Stage 10 - Physiologic maturity, 60 days after silking	Harvest for silage. Grain harvested at this stage would need to be mechanically dried to be stored safely. The rate of drying in the field depends upon climatic conditions, properties of the husks, and other characteristics. Rates of drying may vary among hybrids.

Note: The above is applicable to an adapted, mid-season hybrid in central Iowa

Footnotes

1/ Leonard and Martin, Cereal Crops, p. 139

2/ variety: A named group of plants within a particular cultivated species that is distinguished from the rest of the specie by a character or a group of characters.

3/ hybrid: The first generation offspring of a cross between two individuals differing in one or more genes, i.e. of different genotypes

4/ axil: The angle between the upper side of the leaf and the supporting stem or branch

5/ anther: The pollen-bearing part of the flower. Pollen is the fertilizing clement of flowering plants

CORN: PLANTING AND HARVESTING TIMES

Country	Planting	Harvesting	
(EUROPE)			
Albania	April	August-October	bulk: Sept
Austria	April-May	Sept-October	bulk: mid-Sept to mid-Oct
Belgium	April-May	October	
Bulgaria	April	August-October	bulk: Sept
Czechoslovakia	April-May	late September-end October	bulk: Oct
France	April-May	mid-September-mid-October	
West Germany	April-May	August-September	
Greece	March-April	June-October	bulk: July-Oct
Hungary	April-May	Sept-October	bulk: Sept
Italy	March-early April	early July-Nov	bulk: Aug-Sept
Portugal	March-early April	July-October	bulk: Aug-Sept
Romania	April	Sept-November	bulk: Oct
Spain	March-early April	July-November	bulk: Oct
Yugoslavia	April	Sept-October	bulk: Oct
Switzerland	April-May	August-Sept	
USSR	late April-mid-May	Sept-October	
(NORTH AMERICA)			
Canada	mid-May-beg. June	Sept-November	bulk: Oct-Nov
USA	late March-mid-June	mid-August-mid-December	bulk: end Sept-mid-Nov
(CENTRAL AND SOUTH AMERICA)			
Argentina	September-December	March-June	bulk: March-April
Bolivia	mid-Aug to beg. Dec. (depending on altitude - higher altitudes planted earlier)	April-May	
Brazil			
north	February-March	July-September	
south	October-December	March-June	
Chile	September-December	February-April	bulk: March

Colombia			
first crop	February-April	July-September	bulk: August
second crop	September-October	December-January	
Costa Rica			
first crop	March-May	August-September	bulk: Aug-Dec
second crop	July-September	December-February	
Cuba			
main crop	March-May	July-September	bulk: July-Sept
second crop	September-October	January-February	
Dominican Republic			
first crop	March-April	June-July	
second crop	August-September	December	
Ecuador	December-January	May-June	
El Salvador			
winter crop	May-June	August-December	
summer crop	September-October	December-February	
Guatemala			
first crop	March-May	August-January	bulk: Dec
second crop	September-November	January-March	
Mexico	all year	all year	bulk: July-Dec
Nicaragua			
first crop	May	August-Sept	
second crop	September	December-Jan	
Panama			
first crop	May-June	August-September	
second crop	September-October	December-January	
Paraguay	June-August	January-March	
Peru			
coastal areas	January-June	June-November	
mountain areas	September-December	April-July	
Amazon basin	April-September	July-December	
Uruguay	September-October	April-June	bulk: May
Venezuela			
main crop	March-June	August-Nov	bulk: Oct-Nov
irrigated crop	August-October	December-February	

(MIDDLE EAST AND ASIA)

Cambodia	July-September	December-January
Cyprus	April-July	August-October
India		
spring harvest	October-December	January-April
fall harvest	June-August	August-November
Iran	April-May	July-September
Iraq	June	September-mid-October
Israel		
unirrigated	April-May	August-September
irrigated	April-June	August-October

Jordan	March-April	July-August	
Lebanon	April-June	August-October	
Pakistan	March-April	Aug-December	bulk: Oct-Nov
PRC	mid-March-April	late Aug-Sept	
Philippines	all year	all year	bulk: Aug
Saudi Arabia	May-June	October	
Turkey	February-April	Sept-October	
United Arab Rep.(Syria)	mid-March-mid-May	mid-Aug - mid Sept	
Yemen	July	November	
Thailand	March-May	July-November	bulk: July

(AFRICA)

Algeria	March-April	July-August	
Angola	September-November	May-June	
Belgian Congo and Ruanda-Urundi	November-January	February-May	
Cameroun			
southern rainy area	March-April, Sept.	July, December	
northern dry area	May	September	
Ethopia	April-June	October-January	bulk: Dec-Jan
French Equat. Africa	Sept-November	March-May	
French West Africa			
early crop	March	August-September	
late crop	September	December-January	
Gambia	March-June	June-August	
Ghana			
main crop	February	June-July	bulk: July
second crop	September	December-January	
Kenya			
long rains crop	April-May	October-February	
short rains crop	October-November	June	
Libya	April	July-August	
Madagascar			
first crop	November-January	February-May	
second crop	March-June	July-October	
Mauritius	November-March	February-May	
Morocco	March-May	July-September	
Nigeria and Brit. Cameroons			
north	May-June	August	
south-early	March-April	June-August	
south-late	early September	December-January	
Mozambique	December-January	May-July	
Fed. of Rhodesia, So'ern Rhodesia, Nyasaland	November-December	April-June	
Somalia			
first crop	mid-April	July	
second crop	mid-October	February	
Sudan	April-mid-June	mid-July-September	

Togo	.March-June	July-December
Tunisia.	.April-May.	July-August
Uganda		
main crop	.April-May.	July-September
second crop	.September-October. . . .	January-February
Union of So. Africa. . . .	.October-January.	March-July
Zanzibar	.March.	June-July

(OCEANIA)

Australia	.January-February.	.April-May

Sources: World Crop Harvest Calendar, Food and Agriculture Organization of the United Nations

Planting and Harvesting Seasons in Latin America, USDA-FAS-M-37 July 1958

Planting and Harvesting Seasons for Africa and West Asia, USDA-FAS-M-90 July 1960

FDCD country analysts

Table 1.--Corn As Percentage of World Grain Production

	Total world corn production	Total world grain production (wheat, coarse grains, milled rice)	Corn as percent of total grain
	1,000 M.T.	1,000 M.T.	Percent
1968/69 (Oct.-Sept.)	248.2	1,023.4	24.2
1969/70	264.6	1,032.4	25.6
1970/71	261.0	1,042.2	25.0
1971/72	298.0	1,131.4	26.3
1972/73	291.1	1,101.4	26.4
1973/74	313.2	1,194.1	26.2
1974/75	283.3	1,141.7	24.8

Source: FAS/ERS Grain Data Base

Table 2.--Major corn producers

Country	Average annual production 1968-72	Percent of average annual world total 1968-72	1973 Production	Percent of 1973 world total	1974 Production	Percent of 1974 world total
	1,000 M.T.	Percent	1,000 M.T.	Percent	1,000 M.T.	Percent
U.S.	124,479	45.7	143,429	45.8	118,140	41.7
PRC	25,991	9.5	27,412	8.7	30,023	10.6
Brazil	13,946	5.1	15,000	4.8	16,000	5.6
USSR (Europe and Asia)	9,727	3.6	13,216	4.2	12,142	4.3
Mexico	8,220	3.0	9,000	2.9	7,700	2.7
Argentina	8,202	3.0	9,900	3.2	7,500	2.6
Romania	7,797	2.9	7,397	2.4	7,159	2.5
Yugoslavia	7,387	2.7	8,256	2.6	8,030	2.8
France	7,140	2.6	10,620	3.4	8,800	3.1
South Africa	6,743	2.5	11,105	3.5	10,562	3.7

Source: FAS/ERS Grain Data Base

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